SAFETY RELIEF VALVE TO PROTECT THE COLD MASSES OF THE LHC

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Abstract

A safety relief valve has been developed in order to protect the cold masses of LHC against overpressure while the magnets undergo resistive transition. The valve ensures fast discharge of helium into a separate cryogenic line. The closed valve isolates the static superfluid helium of the cold masses to the separate cryogenic line with a minimum leak rate of less than 0.01 g/s. The valve has a protection device so that the tightness is not reduced by solid particles (from the magnets) in the helium. The Safety Relief Valve can be switched between two operating modes with a set pressure of 12 bar or 20 bar respectively. The main parts of the valve, such as poppet, seat and spindle, are exchangeable under cold conditions.

First measurements and tests have already been carried out. The paper discusses the Safety Relief Valve design and the test results.

1. INTRODUCTION

CERN, the European Organisation for Nuclear Research, located near Geneva (Switzerland), is preparing the Large Hadron Collider (LHC) to extend its present accelerator complex. A proton and ion collider with centre-of-mass energy up to 14 TeV will be installed in the already existing 26.7 km circumference LEP tunnel of CERN. The main components of the LHC are superconducting magnets, operated in superfluid helium at a temperature of about 1.9 K and at an absolute pressure of about 1.4 bar. The superconducting magnets are equipped with Safety Relief Valves enabling superfluid helium discharge in a separate cryogenic line in the event of magnet resistive transition [1] to protect the superconducting magnet against overpressure. The Safety Relief Valve is also used for filling and emptying the cold masses of the superconducting magnets.

2. MAIN VALVE REQUIREMENTS

2.1. Operating Conditions

The Safety Relief Valve operates with superfluid helium at a temperature of 1.9 K and an absolute pressure of 1.4 bar in the valve inlet and with gaseous helium at a temperature of 20 K and an absolute pressure of 1.3 bar in the valve outlet. The superfluid helium is contaminated with solid particles resulting from the manufacture of the superconducting magnets and from powering and depowering cycles, where solid contaminants can be accidentally introduced in a magnet's cold masses. The main contaminants are due to fine grinding of non-metal particles like fibreglass, resins, polyimides and dried insulating paint with a size of 10-700 µm. There may also be larger particles (> 3mm) with similar ingredients and copper filaments, aluminium and stainless steel fragments [2]. During the test of the superconducting magnet the operating temperature is about 300 K and the absolute pressure is about 20 bar. The two operating conditions are called normal and test mode.

2.2. Valve specification

The Safety Relief Valve must be tight in flow direction over the seat with a leak rate less than 0.01 g/s at normal mode. The heat leak by conduction must be less than 0.3 W when the valve is closed, from the thermal anchoring of the valve to the helium at the valve inlet. The size of the valve must be DN 40.

The Safety Relief Valve must possess two safety settings, i.e., the normal mode and the test mode. In normal mode it must be open at a pressure of 12 bar and fully open at a pressure of 20 bar. In test mode it must be open at a pressure of 20 bar and fully open at a pressure of 22 bar. The actuator must be compact, monostable - normally closed -, opening is effected by an external signal and must be equipped with a device to switch between the two opening pressures of the valve.

2.3. Valve characteristic

The Safety Relief Valve must ensure fast discharge while the magnet undergoes resistive transition. For fast discharge it must be fully open in 80 ms (provided that a rate of 100 bar/s is achieved at the valve inlet) and must show a discharge capacity of Kv > 30 m^3/h at full opening. Valve oscillations must be avoided.

3. DESIGN OF THE SAFETY RELIEF VALVE

3.1. Actuator design

The compact actuator (see figure 1) enables the switching of the Safety Relief Valve between the two opening pressures of normal and test mode. It is

equipped with two preloaded springs and a screw jack for switching between the two springs.
The ground plate of the actuator is provided with guiding bars. Spring 1 (used in test mode) is fixed between the spindle plate and preloaded plate 1 using bars. The moving assembly – spindle plate, spring 1, preloaded plate 1 - is flexibly mounted on the guiding bars. Using guiding bars, spring 2 (used in normal mode) with preloaded plate 2 is tightened on the moving assembly.
In normal mode, the moving assembly – spindle plate, spring 1, preloaded plate 1 - becomes a rigid connection, as the preload value of spring 1 equals or exceeds the force of spring 2 when the valve is fully open. The valve spindle acts on spring 2.
In test mode the screw jack installed on the end plate, which is fixed at the end of the guiding bars, fixes preloaded plate 1. Spring 1 is active and opposes the hydraulic force on the valve spindle.
The actuator is to be opened externally, i.e., by an external signal, by means of a pneumatic cylinder with rotary piston acting on the spindle plate.

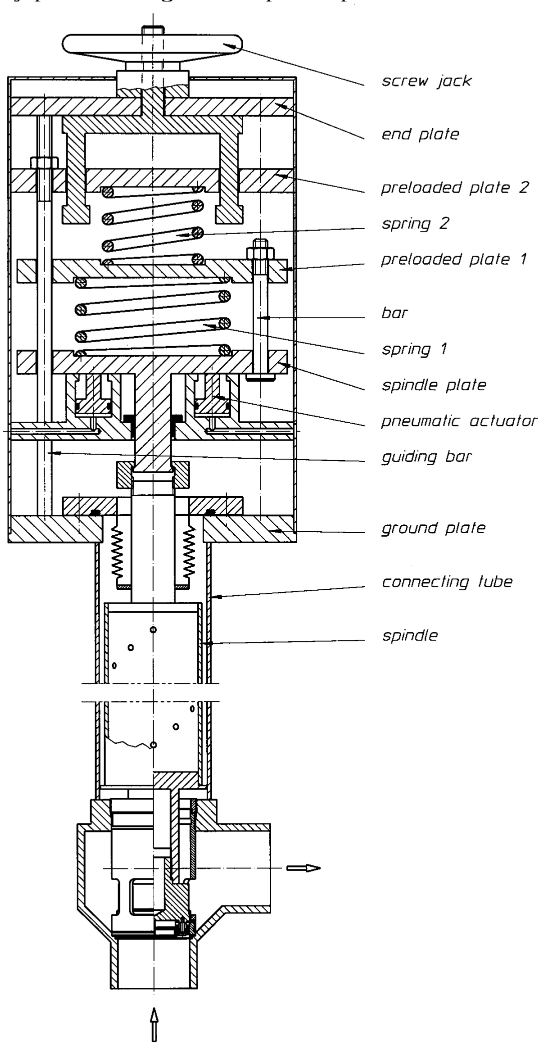

Figure 1: Schematic drawing of the Safety Relief Valve.

3.2. Connection actuator - valve part

By installing a thin-wall stainless steel connecting tube between valve housing and actuator ground plate low heat conduction between the helium in the valve inlet and the actuator located in the atmosphere can be achieved. The internal diameter is dimensioned to enable the replacement of poppet and seat through the connection tube. The spindle also is made of a thin-wall stainless steel tube provided with bore holes for pressure compensation between the spindle's inside and outside.

3.3. Valve design

The Safety Relief Valve is a seat valve with poppet assembly, see figure 2. A fixed stainless steel screen with a mesh width of 50 µm is installed on the stainless steel poppet (orthogonally to the direction of flow); this screen enters in the valve inlet shortly before the poppet arrives the seat. The medium flowing through the valve therefore is filtered; while the valve is fully closing neither seat nor poppet can be damaged by particles contained in the medium.
Along the screen there is a wiper made of polyimide in order to close the gap between valve inlet and screen. This wiper removes particles prevailing on the valve inlet wall. The poppet can be replaced through the spindle. The spindle can be pulled out of the valve after having removed the actuator. The seat is integrated in the guiding cartridge of the poppet and the screen. The guiding cartridge with the integrated seat is replaceable from the stainless steel valve housing using special tool. To replace the integrated seat the guiding cartridge is to be disassembled to its constituents by opening a kind of bayonet connections. The guiding cartridge consists of a rotatable bronze ring (with external thread) fixing the guiding cartridge inside the valve housing. The ring is connected to guiding cylinder 1 (made of stainless steel) for the poppet. Guiding cylinder 1 is centered inside the valve housing by means of a centering ring (made of bronze). The sleeve of guiding cylinder 1 is provided with slots, through which the medium flows when the valve is open. Guiding cylinder 1 is connected to guiding cylinder 2 (also made of bronze), which guides the screen. The valve seat made of polyimide is fixed between the two guiding cylinders. A sealing made of polyimide installed on guiding cylinder 2 serves to seal the guiding cartridge to the valve housing.

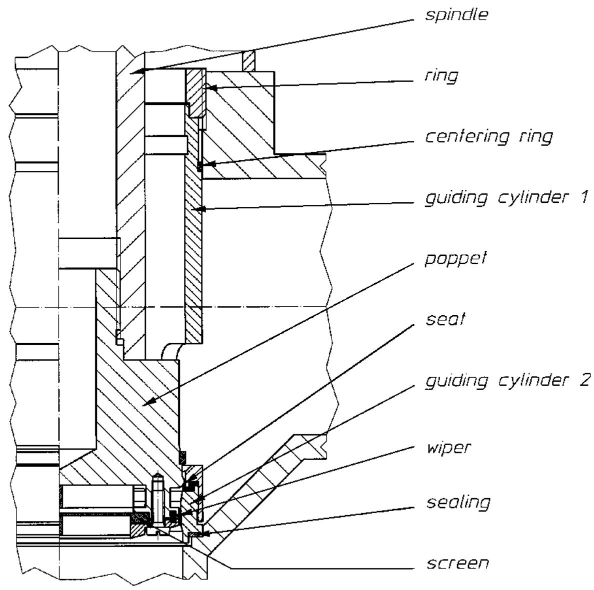

Figure 2: Schematic drawing of the valve part.

3.4. Pros and cons

The outstanding features of the Safety Relief Valve are its applicability in contaminated (solid particles) superfluid helium and its hermetic tightness between valve inlet and valve outlet. Spindle, poppet, screen and seat can be replaced easily. The compact actuator can be switched between the two opening pressures of the valve. The design ensures low heat conduction and a high Kv-value of 35 m^3/h. The disadvantage is that the wiper rubs the guiding cylinder.

4. TEST OF THE SAFETY RELIEF VALVE

The Safety Relief Valve has undergone extensive testing. The following contains a short description of some test methods and results.

Leakage at the valve seat was measured using a bubble tester at T = 77 K and T = 300 K at the valve inlet (using gaseous helium). The tightness of the Safety Relief Valve is < 2 10^{-3} mbar.l.s^{-1} at 77 K, p_{inlet} = 1.1 bar and p_{outlet} = 1.0 bar. On completion of 100 operations and 10 thermal cycles the leakage rate of the valve did not increase. Additionally, tightness was tested after testing of the valve itself using contaminated medium. Contaminants were successfully kept away from the seat; valve tightness was not affected.

The opening behaviour of the valve was tested under static and dynamic conditions. The valve opens harmoniously without sticking in normal mode and in test mode. The dynamic behaviour of the valve was tested by installing the Safety Relief Valve in a test stand consisting of two liquid nitrogen tanks. The Safety Relief Valve was installed in the connecting tube between the two tanks. The liquid nitrogen pressure in the first tank was increased to 25 bar and the opening valve of the first tank was opened. The liquid nitrogen pressure at the Safety Relief Valve increased at a rate of 100 bar/s; the Safety Relief Valve opened at the set pressure of 12 bar and discharged the medium into the second tank. The Safety Relief Valve closed again when the pressure in the first tank was reduced.

Figure 3 shows a typical diagram of the valve's dynamics indicating the pressure in valve inlet and outlet, the opening stroke as a function of time.

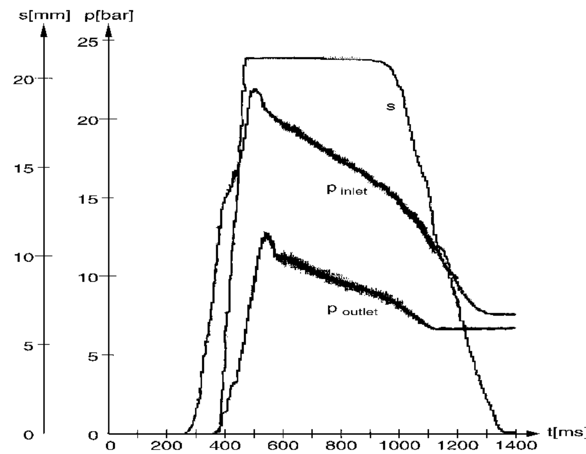

Figure 3: Typical diagram of the valve dynamic

The diagram shows that the valve harmoniously and fully opens within 80 ms. The opening stroke corresponds to the opening pressure. The valve does not show any stroke oscillations that are not reflected in a variation of the opening pressure. The Safety Relief Valve fully closes when the valve inlet pressure drops.

Further tests on the valve itself, in particular tests concerning heat conduction, leakage at 1.9 K and performance tests in a test magnet, will be carried out by CERN.

5. CONCLUSION

The herein described Safety Relief Valve meets the demands in the aspects that have been examined. The tests indeed gave proof of the good dynamic behaviour of the valve, its exact opening and its high tightness even when using contaminated fluid. Extensive testing with superfluid helium and the comparison with other safety valves will be carried out by CERN.

REFERENCES

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